Field test of new poplar clone in Shangdong Province

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Abstract: Poplar is one of the dominant tree species for the establishment of fast growing plantations in Shandong Province. Eighteen poplar clones belonging to *Populus aigeiros* section were introduced from Italy, Turkey and domestic regions. *Populus deltoides cv.* 'Lux' I-69/55 (I-69), which was widely used in Shandong Province, China, was taken as control clone (I-69). Following a randomized complete block design, seedling test and controlled afforestation trials were carried out at Juxian County, Caoxian County and Laiyang City. The results showed that the poplar clone (*Populus x euramericana cv.* '102/74'), namely 102/74, performed well both in terms of adaptability and growth rate. The mean height of 13.9 m (H), diameter at breast height of 18.0 cm (DBH) and volume growth of 0.1445 m^3 (V) were 2.2 %, 21.6% and 52.9 % higher than those of I-69 (CK), respectively, at the age of 5 years at three experimental sites. Moreover, the clone can be propagated easily and showed high resistance to poplar disease, pest as well as salinity and had longer growing period. Furthermore, wood basic density and fiber length of new poplar clone (102/74) were as same as I-69 (CK). It was concluded that the selected clone (102/74) was ideal for the establishment of fast-growing poplar plantations, especially for the pulpwood plantations in Shandong Province.

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Introduction

Poplar clones, especially *Populus aigeiros*, were widely adopted for establishment of fast-growing plantations in Shandong Province. However, neither *Populus deltoides* nor *Populus x euramericana* were naturally distributed in the region (Meng 1989). To enrich poplar varieties, the 19 poplar clones, belonging to *P. deltoides* and *P. x euramericana*, had been introduced from Italy, Turkey and domestic regions to Shandong Province from 1986 to 1987. In this study, seedling test and afforestation trials of those clones were conducted at three experimental sites, and one superior poplar clone (*P. x euramericana cv.* '102/74'), namely 102/74, was selected based on the parameters of growth rate, survival rate, resistance to pest and disease, adaptability to the local climatic conditions, soil types, and wood properties.

Materials and methods

Natural conditions in the originating countries and introduced region

Italy has a typical Mediterranean climate, with an average annual temperature of 12 °C and annual precipitation of 500-1000 mm. The rich plains of Italy are suitable for the growth of poplar plantations (Avanzo *et al.* 1985). With the promotion of International Poplar Commission (IPC), FAO, Italian experts made a great of achievements both in poplar breeding and cultivation in the last few decades (Giordano 1976), and poplar dominated in forest plantations in the country (FAO, 1979).

With a monsoon climate, Shandong Province, China, had four distinguished seasons. Most of the precipitation concentrates in summer and cold and dry wind prevailed in the winter (Table 1). Due to the high groundwater level and good air conditions in the soil, which favors the growth of poplar, most of the plains in Shandong Province are suitable for the establishment of poplar plantations.

Materials

Of 19 introduced clones: 8 species were introduced from Italy: 102/74 (*P. x euramericana cv.* '102/74'), 2KEN8 (*P. x euramericana* '*2KEN8*'), 302 (*P. x euramericana* '*302 San Giacomo*'), BL (*P. x euramericana* '*BL Costanzo*'), Adige (*P. x euramericana* '*Adige*'), Stella (*P. x euramericana* '*Stella Ostigliese*'), PAN (*P. x euramericana* '*PAN*') and 34/83 (*P. deltoides x P. ciliata* '*34/83*'); 2 species were introduced from Turkey: PE-19-66 (*P. deltoides cv.* '*PE-19-66*') and S307-26 (*P. deltoides cv.* '*S307-26*'); 7 species were introduced from Chinese Academy of Forestry: W-13 (*P. x euramericana cv.* '*W-13*'), W-141 (*P. x euramericana cv.* '*W-141*'), L916-210 (*P. x euramericana cv.* '*L916-210*'), W-29 (*P. x euramericana cv.* '*W-29*'), 254-55 (*P. x euramericana cv.* '*254-55*'), Zhonglin101 (*P. x euramericana cv.* '*zhonglin101*') and Zhongxia3 (*P. deltoides cv.* '*Zhongxia3*'); 1 species was introduced from Nanjing Forestry University: NL669 (*P. deltoides cv.* '*NL669*'); and the clone I-69 (*P. deltoides cv.* '*Lux' I-69/55*), which

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was then commercially used and commonly cultivated in native area, was used as control.

Methods

Seedling test

Seedling test was conducted separately at Juxian County, Caoxian County and Laiyang City. With a planting density of 40 cm×70 cm, 3-5 replications and 10-50 cuttings for each, complete random block design was adopted. No special measures were taken except for the routine tending practice. Growth indices including survival rate, height (H) and ground diameter (D_0) of each clone were measured at the end of the growing season.

Table1. Meteorological parameters in the trial sites*

Trial sites	Average temperature/°C	Extreme temperature /°C		Precipitation /mm	Annual sunshine hours /h	Frost-free days/d	Extreme temperature/°C	Soil type
		Highest	Lowest					
Caoxian	13.8	43.7	-18.1	707.9	2637.5	212	Sandy loam	
Laiyang	11.2	38.9	-24.0	759.0	2657.3	173	Medium loam	
Juxian	12.1	39.4	-25.6	873.0	2532.2	203	Light loam	

Note: *----The data came from Meteorological Bureau of Shandong Province.

Afforestation trials

Experimental forests with different plant and row spacing had been established at Juxian County (5 m×5 m), Caoxian County (3 m×5 m) and Laiyang City (4 m×6 m). Completed random block design was adopted, with 4 replications, 9 or 12 trees for each block. The protective lines of 3-6 were also planted around the experimental forests.

Permanent plots were established in the experimental forests. Growth indices including height (H) and diameter at breast height ($D_{1.3}$) were measured each year and occurrence of disease and pest was also recorded. Phenological phases were observed at Juxian experimental forest in 1991. Wood samples were taken from three 5-yr-old trees and their fiber length and basic density were measured following the national standards (GB1943-92). With an increment borer, five 5-mm (diameter) cores per tree sampled were taken from pith to bark (xylem only). The outmost growth ring was used to measure the fiber length with hydrogen nitrate method, while the left rings were used to measure the basic density with water soaking method.

Test of resistance to soil salinity was carried out at Shouguang Saline Soil Experiment Station, Shandong Academy of Forestry, where the salt content in the soil was 0.2%. A completed random block design was adopted, with a planting density of 30 cm×70 cm, 4 replications, 20 cuttings per block,. Growth indices including survival rate, height (H) as well as ground diameter (D_0) of each clone were measured in June.

Data analysis

Mean value of the each treatment was used for the variance analysis. The singletree volume was calculated by using formula (1):

$$V=f_{1.3}G_{1.3}H \quad (1)$$

where, V is the singletree volume, $f_{1.3}$ is the breast-height form factor, $G_{1.3}$ is the basal area at breast height; H is the tree height. Data were analyzed by statistical models of SAS Institute Inc (Huang *et al* 2001).

Results

Seedling test

Survival rate of poplar clone 102/74 was generally higher than that of I-69 (CK) at all the experimental sites. Mean value of survival rate of 102/74 was as high as 89.3%. Moreover, mean H and D_0 of 102/74 were same or higher than those of I-69 (CK), (Table 2). The results showed that 102/74 clone had relatively high survival rate and could be propagated easily.

Table 2. Survival rates and seedling growth of new poplar clone (102/74) and I-69 (CK) at nursery stage at different experimental sites

Clone	Survival rate (%)				H/m				D_0/cm			
	Juxian	Caoxian	Laiyang	Mean	Juxian	Caoxian	Laiyang	Mean	Juxian	Caoxian	Laiyang	Mean
102/74	94.0	90.0	84.0	89.3	3.6	2.7	2.6	3.0	2.8	2.3	2.5	2.5
I-69 (CK)	84.1	85.7	80.0	83.3	3.4	2.9	2.5	3.0	2.6	2.1	2.1	2.3

Volume growth

Growth performance was considered as one of the key parameters in selecting poplar clones for the establishment of fast-growing poplar plantations. Variance of mean H, $D_{1.3}$ and V of singletree of the tested clones (Table 3) at different experiment sites had been analyzed by T-test (LSD), (Table 4, 5). The results showed that the differences of H, $D_{1.3}$ and V of singletree of tested clones at all experimental sites were significant except for that of height of poplar at Lai-

yang site.

To a significant difference of I-69 (CK) at 1% level (P_r>F=0.0001<0.01), (Table 4), the mean singletree volumes of 102/74, S307-26, 802 and PE-19-66 clones at age of 5 were 55.1%, 45.9%, 43.8% and 25.7% respectively higher than those of I-69 (CK) at Juxian site, were 68.9%, 64.3% and 62.5% and 50.5% respectively higher than those of I-69 (CK) at Laiyuan site, and were 33.4%, 28.0%, 8.6%, and 8.4% higher than those of I-69 (CK), respectively at Caoxian site (Table 5).

Based on the results analyzed above, it was found that new poplar clone (102/74) generally grew faster than I-69 (CK), and mean values of V of single tree was significantly different with that of I-69 (CK) at all the experimental sites. So, it was primarily selected for further test.

Table 3. Growth indices at different experimental sites at the age of 5 years

Clone	Juxian (5 m×5 m)				Laiyang (4 m×6 m)				Caoxian (3 m×6 m)			
	H/m	$D_{1.3}$/cm	V/m^3	V/V(I-69)%	H/m	$D_{1.3}$/cm	V/m^3	V/V(I-69)%	H/m	$D_{1.3}$/cm	V/m^3	V/V(I-69)%
102/74	16.3	19.3	0.1909	155.2	12.8	18.2	0.1351	168.7	12.5	16.5	0.1074	133.4
I-69 (CK)	15.9	15.7	0.1230	100.0	12.1	14.5	0.0801	100.0	12.7	14.1	0.0805	100.0

Table 4. Variance analysis of average H, $D_{1.3}$ and V of single tree at different experimental sites

Item	Juxian			Laiyang			Caoxian		
	H	$D_{1.3}$	V	H	$D_{1.3}$	V	H	$D_{1.3}$	V
F-value	44.53**	352.20**	296.31**	0.82	4.77**	2.88**	4.67**	2.92**	2.74*
Pr>F	<0.01	<0.01	<0.01	0.62ns	<0.01	<0.01	<0.01	<0.01	<0.05

Notes: **----Significant at 1% level; *----Significant at 5% level; ns ----Not significant at 5% level.

Table 5. T-test ($LSD_{0.05}$) of V of tested clones at three sites at the age of 5 years

Clone	Juxian site		Laiyang site			Caoxian site		
	V/m^3	V/V (I-69) (%)	Clone	V/m^3	V/V (I-69) (%)	Clone	V/m^3	V/V (I-69) (%)
102/74	0.1908^{A}	155.1	102/74	0.1351^{A}	168.9	102/74	0.1074^{A}	133.4
S307-26	0.1795^{B}	145.9	PE-19-66	0.1314^{AB}	164.3	NL669	0.1030^{AB}	128.0
802	0.1769^{B}	143.8	S307-26	0.1300^{AB}	162.5	S307-26	0.0874^{ABC}	108.6
PE-19-66	0.1546^{C}	125.7	802	0.1204^{ABC}	150.5	802	0.0873^{ABC}	108.4
I-69 (CK)	0.1230^{D}	100.0	254-55	0.0957^{ABC}	119.6	Zhonglin101	0.0832^{BCD}	103.4
34/83	0.1092^{E}	88.8	W-29	0.0921^{ABC}	115.1	I-69 (CK)	0.0805^{CD}	100.0
BL	0.1003^{EF}	81.5	L916-210	0.0903^{BC}	112.9	W-13	0.0786^{CD}	97.6
302	0.0936^{F}	76.1	W-141	0.0888^{BC}	111.0	254-55	0.0758^{CD}	94.2
Zhongxia3	0.0747^{G}	60.7	W-13	0.0827^{C}	103.4	W-141	0.0755^{CD}	93.8
2KEN8	0.0661^{G}	53.7	I-69 (CK)	0.0800^{C}	100.0	W-29	0.0748^{CD}	92.9
PAN	0.0498^{H}	40.5	Zhonglin101	0.0793^{C}	99.1	L916-210	0.0719^{CD}	89.3
Stella	0.0155^{I}	12.6	NL669	0.0784^{C}	98.0	PE-19-66	0.0631^{D}	78.4
LSD			LSD			LSD		
(0.05)=0.0010			(0.05)=0.010			(0.05)=0.0153		
CV=2.0049			CV=2.0423			CV=2.1788		

Notes: No significant difference among the clones with same letters and significant difference among the clones with different letters at 5% level.

Survival rates

The changes in survival rate of both new poplar clone (102/74) and I-69 (CK) at the afforestation sites were observed in different climatic conditions and soil types (Fig. 1). However, survival rate of 102/74 was generally higher than that of I-69 (CK) at all afforestation sites, the result indicated that the 102/74 has a higher adaptability to the local climate and soil conditions (Table 1).

Resistance to salinity

Tree height (H), ground diameter (D_0) as well as survival rate of 102/74 clone were generally higher than those of I-69 (CK) in the soil with 0.2% salt content. The results showed that the new poplar clone (102/74) is more resistant to salinity than I-69 (CK), (Fig. 2).

Resistance to pest and disease

Resistance to pest and disease is one of the most important criteria in selection of new poplar cultivars (FAO Forestry 1985). The observation showed that resistance of 102/74 to *Apriona germari*, *Anoplophora glabripennis* and *Phoma eucalyptica* was generally higher than that of I-69 (CK), (Table 6).

Table 6. Resistance of new poplar clone (102/74) and I-69 (CK) to poplar pest and disease

Clone	*Apriona germari*	*Anoplophora glabripennis*	*Phoma eucalyptica*	
	Number per tree	Percentage of tree attacked (%)	Number of larva per tree	Percentage of infected trees (%)
102/74	0.39	21.6	0.08	9.4
I-69(CK)	0.40	40.0	0	12.2

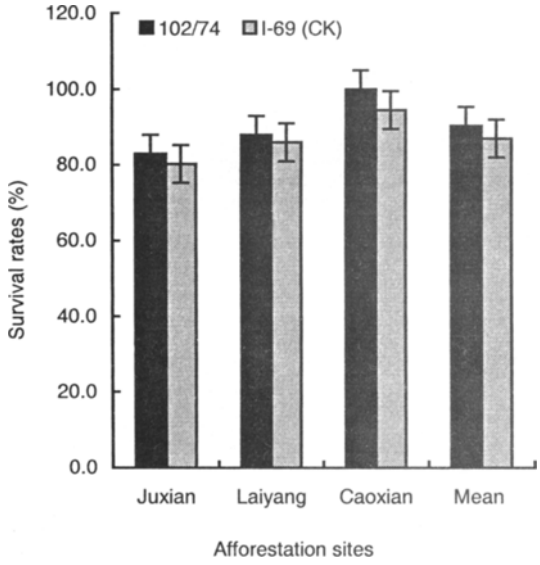

Fig. 1 Survival rates of 102/74 and I-69 (CK) clones at afforestation sites of Juxian, Laiyang and Caoxian

Wood property

Wood property of I-69 (CK) was commonly believed to be the best among clones in *P. aigerios* and it was highly recommended for wood pulp production. Results of variance analysis showed that there were no significant differences in fiber length and basic density between 102/74 and I-69 (CK) clones tested, indicating both 102/74 and I-69 (CK) were suitable for papermaking (Table 7).

Table 7. Fiber length and basic density of 102/74 and I-69 (CK) clones tested

Clone	Fiber length/mm	Basic density/g·cm^{-3}
102/74	0.92	0.404
I-69 (CK)	0.98	0.400
F-value	9.00^{ns}	0.64^{ns}
P_r>*F*	0.0955	0.5076

Note: ^{ns}---- Not significant at 5%level.

Conclusions and discussion

Survival rate and growth rate were the most important criteria for the selection and implementation of new poplar cultivars. Survival rates of poplar clones in P. x euramericana were usually higher than those in P. deltoides in Shandong Province where the arid climate prevailed (Huang 1988). So, it was practically important to select new poplar clones in *P. x euramericana* with high survival rate and fast growth rate. Control (I-69) was introduced into Shandong Province in the early 1980s and then widely planted in the region. However, the arid climate in the region made it difficult to survive, which resulted in the limited implementation in the region. Moreover, degradation of I-69 (CK) was observed in recent years. Undoubtedly, the introduction of new poplar clone (102/74) provided an alternative for the establishment of poplar plantations. Furthermore, the introduced clone (102/74) grew well under various climatic conditions and soil types, implying high ecological adaptability in Shandong Province (Table 1). After 5 years, in multi-site test, its growth performance was proved to be stable and was suitable for the establishment of fast-growing poplar plantations within Shandong Province.

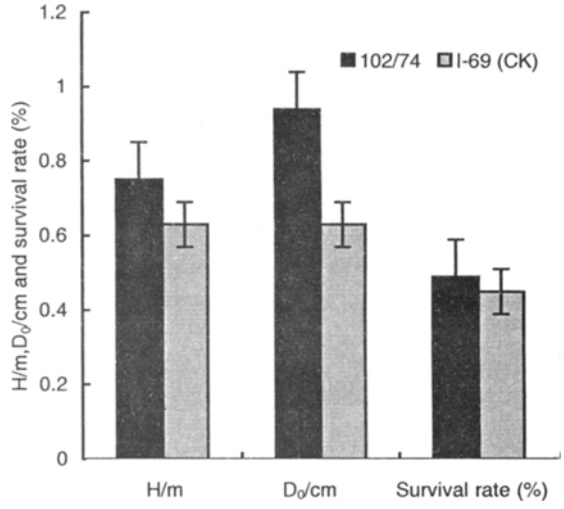

Fig. 2 Growth performance of 102/74 and I-69 (CK) clones in the soil with 0.2% salt content

One of the branches in poplar breeding was to breed new clones for pulpwood. Fiber length and basic density were two important criteria to measure the quantity and quality of fiber production (Browning 1957). Basic density was positively correlated with wood hardness and mechanical intensity while fiber length had close link with wood pulp property (Zobel *et al.* 1984). Many studies showed that there were considerable changes in wood properties among various poplar clones and they were mainly controlled by heredity (Glichrist *et al.* 1995). However, this was not observed in our study. One possible reason might be that the two clones had very close heredity distance.

Although the introduced clone (102/74) had longer annual growth period than I-69 (CK), the relationship between biological production and annual growth period

remained unclear. Results of some studies showed that volume yield had close correlation with the dates of leaf color change and leaf falling (Xie *et al.*1995) as well as other indices such as photosynthesis rate, which were determined by genotypes of the clones (Sun *et al.* 2003).

The results of field test showed that the two clones had resistibility to poplar pest, disease and salinity. However, details of their resistance to adverse environment (Drought *et al.*) should be further studied.

Study on the *Cryptomeria japonica* showed that trees with faster growth rate usually had longer fiber length and lower wood density than those with lower growth rate (Zobel *et al.* 1989). However, it did not mean that all the tree species followed the same rule. Many studies showed that the traits of growth rate, wood density and fiber length of poplar clones were controlled by different genes and they could be selected independently (Jiang *et al.* 1994). Fiber length and basic density of the introduced clone (102/74) accord with the standards for papermaking and it is ideal poplar clone for the establishment of pulpwood plantations. However, detail wood properties and potentials for papermaking (wood pulp characters) should be further studied.

The new poplar clone (102/74) was introduced from Italy and it was categorized as *P. x euramericana*. However, specimen and detail morphological description of the clone were needed for further identification.

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Table 8. Phenological phases of new poplar clone (102/74) and I-69 (CK) at Juxian site

Clone	Bud inflating	Leafing date		Branch putting forth	Ceasing of short branch	Ceasing of long branch	Change of leaf color	Leaf falling		Growth period/d
		Beginning	Prevailing					Prevailing	Ending	
102/74	04.13	04.22	04.24	04.26	07.26	08.22	10.28	11.4	11.8	212
I-69 (CK)	04.17	04.25	04.27	04.30	07.27	09.02	10.20	11.2	11.10	207

Note: Observation was taken in 1991

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